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I&I Evaluation Report
Project 994

Sewershed Study and Plan
Sanitary Sewer Overflow Consent Decree
Civil Action No. JFM-02-1524

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in association with



Infiltration and Inflow (I&I) Report

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 Yearly hydrograph of every site (Q and rain)
 Yearly scattergraph of every site
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Executive Summary

As part of Baltimore City Project No. 994, Rummel, Klepper & Kahl, LLP and KCI Technologies, Inc. have conducted analyses of infiltration and inflow (I/I) into the City's sewer collection system within the Jones Falls sewershed. This report outlines the results of the I/I analysis.

To fully understand the dynamics of the sewage collection system, the City completed a detailed City-wide monitoring program. The monitoring program consisted of over 350 flow monitors City-wide, with 78 of the meters located within the Jones Falls sewershed from May 9, 2006 to May 18, 2007. Some meters deemed long term meters have stayed in place. In addition to the flow monitors, 20 rain gauges were installed City-wide with some gauges installed outside of the City limits.

Slicer is a tool developed by ADS Environmental Services, Inc. to find the locations of the worst inflow/infiltration problems in a sanitary sewer collection system using rainfall and flow data.

For this project, BI was normalized based on inch-diameter-miles (IDM). A total of 29 storms during the metering period met the criteria for a storm event as defined by the global setting.

For this project, RDII was normalized based on linear footage (mg/l.f./in-of-rain). A graphical technique for evaluating and comparing the performance of sewershed basins under widely varying rain events is the Q vs. I diagram. The slope (S) of the regression line on the Q vs. I plot was used in the following equation to obtain the capture coefficient (R).

Among the ten basins with the highest base infiltrations rates, two are located within the Western Run sub-sewershed, two are within the Upper Jones Falls sub-sewershed, two are in the Stony Run sub-sewershed, and one each are in the Barclay Street, Hampton Avenue, Maryland Avenue and Greenmount Avenue sub-sewersheds.

From a sub-sewershed basis, the Maryland Avenue sub-sewershed has the highest base infiltration rate. The Barclay Avenue has a rate 95 percent of that of Maryland Avenue. The sub-sewershed with the lowest infiltration rate is Greenmount Avenue. The Western Run sub-sewershed is also low, less than one percent higher than the rate for the Greenmount Avenue sub-sewershed.

The base infiltration rate coming from Baltimore County is approximately 31 percent of the average daily flow based on the metering data.

The basin with the greatest RDII severity is JF07 which is located within the Maryland Avenue. There are a total of 17 basins which have a normalized RDII value greater than 10 MG per linear foot per inch of rainfall. Of these 17 basins, seven are located within the Western Run sub-sewershed, three each are in the Stony Run and Greenmount Avenue sub-sewersheds, two are in the Upper Jones Falls sub-sewershed, and one each are in the Maryland Avenue and Barclay Street sub-sewersheds.

On a sub-sewershed basis, the Maryland Avenue sub-sewershed has the worst severity of RDII. Other sub-sewersheds with relatively high rates of RDII are Western Run, Stony Run and Greenmount Avenue. The sub-sewershed with the lowest rate of RDII is the Upper Jones Falls. The Bolton Hill and Hampton Avenue sub-sewersheds also have relatively low rates of RDII.

A review of the scattergraph plots shows evidence of possible sanitary sewer overflows (SSOs). The scattergraph for Meter JF04, in the Greenmont sub-sewershed, indicates evidence of a possible upstream overflow. The scattergraph for Meter JF10, in the Barclay Street sub-sewershed, indicates evidence of a possible SSO downstream of this site. A possible upstream SSO is suggested by the scattergraph for Meter JF40, in the Upper Jones Falls sub-sewershed. Scattergraphs that indicate possible bottlenecks include JF07 in the Maryland Avenue sub-sewershed, JF09 in the Barclay Street sub-sewershed, JF22 and JF23 in the Stony Run sub-sewershed, JF41 and JF47 in the Upper Jones Falls sub-sewershed, and JFWR18 and JFWRR01 in the Western Run sub-sewershed.

The scattergraphs were also reviewed to assess the hydraulic performance of the collection system. Within the Greenmount Avenue sub-sewershed, three of the six meters show no surcharging occurred during the metering period. For the Maryland Avenue sub-sewershed, one of two meters did not surcharge during the metering period. In the Barclay Street sub-sewershed, which contains two metering basins, the downstream meter, JF09, experienced some surcharging to a maximum depth of approximately four feet. The five meters within the Bolton Hill sub-sewershed indicate infrequent or no surcharging. For the Hampton Avenue sub-sewershed, four of the five meters indicate some, but infrequent, surcharging. In the Stony Run sub-sewershed, while the upper portions of this sub-sewershed show little or no surcharging, the lower portion indicates some significant surcharging. In the Upper Jones Falls sub-sewershed, nine of the sixteen meters either show no surcharging or surcharged depths of 3.5 feet or less. At the other meters, there are some frequent and significant surcharge depths. In the Western Run sub-sewershed, there are a total of 18 meters. Nine of these meters recorded no instances of surcharging, four had a maximum surcharged depth of two feet or less, and one had a maximum depth of less than four feet. The four remaining meters has maximum depths of 9.3 to 13.3 feet. Two of these meters, JFWRR01 and JFWR01, are located along the main Western Run Interceptor near the Jones Falls trunk sewer.

Introduction

1.1 Sewershed Description

The Jones Falls Sewershed encompasses approximately 16.5 square miles within the City of Baltimore and the total area including Baltimore County encompasses approximately 39 square miles. Sewage from Baltimore County flows into the City's Jones Falls sewershed at six metered locations. The sewershed population within the City is approximately 144,000. The entire sewershed has a population of approximately 192,000. The entire Jones Falls sewershed is over 80 percent developed. The Jones Falls Sewershed within the City of Baltimore includes over 1,611,000 linear feet (LF) of gravity sewer ranging from 8- to 100-inches in diameter; approximately 8,000 manholes and structures; and 37,000 LF of force main, pressure sewer and siphons. The Jones Falls collection system also includes one existing pumping station and one that is currently under construction. The Jones Falls Pumping Station is located at the intersection of Clipper Mill Road and Ash Street and was originally constructed in 1947. The most recent rehabilitation was in 2007, which increased the capacity of the station to 55 million gallons per day (mgd). The Stony Run Pumping station is currently under construction with a scheduled completion date of December 2008. The station is located near the intersection of 29th Street and Sisson Street. The station, which would operate only during wet-weather events, will have a capacity of 20 mgd. The flows from the station will be pumped into a 30-inch force main that connects to the 54-inch Jones Falls Pressure Sewer at the intersection of 29th Street and Huntingdon Avenue.

The Jones Falls sewershed encompasses a section in the north central portion of the City, as depicted on Figure 1. The boundaries are roughly York Road to the east, Park Heights Avenue on the west, the City-County line on the north and Preston Street on the south. The major waterway within the sewershed is the Jones Falls which has two main tributaries, Western Run and Stony Run. The Jones Falls is the largest of Baltimore's three stream valleys and originates from a spring located north of Greenspring Valley Road, east of Garrison Forest Road in Baltimore County. Western Run enters the Jones Falls near the intersection of Smith Avenue and Falls Road in the Mount Washington community of the City. Stony Run enters the Jones Falls near the 29th Street Bridge over the Jones Falls. Two significant lakes within the sewershed are Druid Lake located within the City, and Lake Roland in the County.

The Jones Falls Sewershed consists of a total of nine sub-sewersheds. These are listed in Table 1 below:

TABLE 1
SUB-SEWERSHEDS WITHIN THE JONES FALLS SEWERSHED
Upper Jones Falls
Lower Jones Falls
Western Run
Stony Run
Hampton Avenue
Barclay Street
Greenmount Avenue
Bolton Hill
Maryland Avenue

The boundaries for each of the sub-sewersheds are depicted on Figure 1.

The development within the Jones Falls sewershed is primarily residential with some areas of industrial, commercial and institutional development. The most significant area of industrial development is along the Jones Falls corridor from near Cold Spring Lane to the Jones Falls Expressway ramp to Falls Road. Areas of institutional development include Sinai Hospital in the Western Run sub-sewershed and Johns Hopkins University in the Stony Run sub-sewershed.

1.2 Objectives of the Study

The City established two main objectives for the Comprehensive Flow Monitoring Program:

1. Collect accurate rainfall and flow data – The program would accomplish this goal by requiring:
 - The use of the latest metering technology and Doppler radar rainfall measurement.
 - Daily data collection using wireless communication, which identifies equipment malfunctions sooner and, therefore, maximizes rainfall and flow data availability.
 - A multiple-tier data processing and data quality assurance by the service providers and the City.
2. Standardize I&I evaluation – This goal would be accomplished by:
 - Establishing standard I&I evaluation parameters and definitions for the use of all Sewershed Consultants.
 - Requiring all Sewershed Consultants to use a standard I&I evaluation software (Slicer.com®, a registered mark of ADS Corporation).

1.3 Recently Completed Sanitary Projects

There were a number of Paragraph 8 sanitary sewer construction projects under construction during the flow monitoring period. These projects are listed in the table below:

TABLE 2 PARAGRAPH 8 PROJECTS IN THE JONES FALLS SEWERSHED UNDER CONSTRUCTION DURING THE FLOW MONITORING PERIOD			
Sanitary Contract No.	Sub-Sewershed	Description	Completion Date
SC800	Lower Jones Falls	Upgrade ex force main to handle increased flows from the rehabilitated Jones Fall PS as well as additional flows from the Stony Run pumping station.	November 2007
SC818	Lower Jones Falls	Install 7,900' of 36" to 42" sewer	June 2006
SC819R	Upper Stony Run	Line approx. 5,560 linear feet of 12" to 18" pipe and install approx. 760 linear feet of 15" to 18" pipe.	February 2007
SC820	Greenmount Avenue	Line approximately 9,300 linear feet of 12 to 36-inch sewer and install approximately 885 linear feet of new 10-inch to 15-inch sewer	May 2007
SC822	Lower Jones Falls	Upgrade existing pumping station to handle at least 50 mgd	November 2007
SC824	Upper Jones Falls	Replace 7,080 linear feet of 48" sewer	December 2006
SC833	Greenmount Avenue	Install 7,325 linear feet of 36- to 42-inch parallel relief sewer from Bonaparte Avenue to the High Level interceptor on Eager Street	January 2008
SC838	Middle Stony Run	Line approx. 5,410 linear feet of 12" to 18" pipe and install approx. 3,340 linear feet of 15" to 24" pipe.	April 2007

As indicated in the above table, there were two projects were under construction in the Greenmount sub-sewershed during the flow metering period. Since project SC833 was still under construction at the end of the metering period, and involved construction of a relief sewer, this project is

believed to have no effect on the flow metering. A review of the metering data shows that for at least two of the meters in this sub-sewershed, there were lower depths after a portion of the SC820 construction project was completed.

There were also two projects that were under construction in the Stony Run sewershed. Project SC819R began prior to the start of the flow metering and was completed approximately three months prior to the completion of the flow metering. Project SC838 began after the start of the flow metering and was completed approximately one month before the end of the flow metering. At least one meter, JF25, indicates lower depths as the construction proceeded.

Three projects were under construction during the flow metering period in the Lower Jones Falls sub-sewershed. Two of the projects involved upgrading the Jones Falls Pumping Station and installing a new force main from the pumping station. Neither of these projects is expected to have affected the flow metering. Project SC818 was completed approximately one month after the start of the metering period, and would thus have little change for the majority of the metering period.

There was one project in the Upper Jones Falls sewershed during the metering period. Project SC824 involved replacing the existing sewer with a 48-inch sewer and was completed approximately seven months into the metering period. There are, however, only two meters downstream of this construction. One meter, JFINL, has no data prior to the completion of the construction and the other meter, JFPS, is affected by the operation of the Jones Falls Pumping Station.

1.4 BaSES Manual Requirements

The Baltimore Sewer Evaluation Standards Manual (BaSES), developed by the City for the sewershed studies, establishes guidelines for the I&I analyses and outlines additional requirements.

2.0 Flow Monitoring Program

2.1 Overall Description

To fully understand the dynamics of the sewage collection system, the City completed a detailed City-wide monitoring program. The program consisted of flow meters within the City's collection system and rain gauges spread throughout the City and County. The monitors measured depth and velocity, from which flow was calculated at five minute intervals. The monitoring program consisted of over 350 flow monitors City-wide, with 78 of the meters located within the Jones Falls sewershed from May 9, 2006 to May 18, 2007. Some meters deemed long term meters have stayed in place. See Table 4 at the end of this report for a list of meters, their sub-basin, purpose, and installation history and Figure 1 for a location map of the meters and rain gauges. Figure 2 depicts a schematic of the monitoring plan. In addition to the flow monitors, 20 rain gauges were installed City-wide with some gauges installed outside of the City limits. All 20 rain gauges were utilized in conjunction with the generated radar rainfall for analysis.

2.2 Summary Description of the Metering Network Within the Sewershed

The 78 flow-monitoring sites within the Jones Falls Sewershed were selected depending on the use of the flow data. The majority of the sites, 62, were installed for infiltration and inflow (I&I) evaluation; whereas, 16 of the sites were installed for the calibration of the hydraulic model. Table 4 lists the meters and their primary purpose and installation history. Using the City's Geographical Information System (GIS) the metering sites for I&I evaluation were selected at a meter density of approximately one for every 25,000 linear feet of sewer pipe. Figure 2 is a flow schematic of the meter network within the Jones Falls Sewershed.

2.3 Flow Metering

2.3.1 Equipment Description

The meters used for the City-wide Flow Monitoring Program were depth-velocity meters designed to calculate flow based on measured depths and velocities in sanitary sewer pipes under free-flow and surcharged conditions. The primary depth sensor is ultrasonic with a resolution to the nearest 0.01 foot. The meters have level measurement redundancy, in the form of a pressure sensor, with accuracy of +/- .25 percent of full scale. The project required that the primary velocity sensor use Doppler technology, capable of measuring flow velocities in the range between -5 to +15 feet per second. The sensors were securely attached to the pipe by means of metal bands or anchoring hardware designed specifically for that purpose.

2.3.2 Installation

Every flow monitoring location was verified by the flow monitoring Contractor by performing a thorough site investigation, including descending the manhole. The hydraulic conditions at each site dictated the metering equipment selection and optimal sensor placement. If a location was deemed unsuitable for flow monitoring, the Contractor was required to coordinate with the City and to investigate up to two alternate sites for consideration. The Contractor also checked for debris in the manhole that could impact data quality. For each location the Contractor prepared and submitted an electronic site investigation report, which included a general site location map, a sketch of the installation, the physical characteristics (diameter or other measurements as necessary to define the pipe cross-section, material, etc.) of the sewer pipe in which the sensors would be installed, manhole depth, and other comments deemed pertinent by the Contractor. In addition, survey-grade GPS (Maryland State Plane - +/- 0.5 inch) coordinates, pipe inverts and rim elevations; and three digital images of the site were required, including one showing the sensor installation.

The Contractor was required to evaluate the level of silt and debris at each monitoring location, and to provide sewer cleaning to ensure accuracy and reliability at each metering site. In case of odd-shape pipes, or in sites where debris or sediment was present, the Contractor developed a profile and accurately determine the cross sectional area of the pipe at the depth-measuring point. A typical flow monitor installation included the primary ultrasonic depth sensor mounted at the crown of the pipe, a redundant depth sensor mounted in the invert, and a Doppler primary velocity sensor mounted in or near the invert of the pipe. All flow meters and rain gauges were synchronized in time to the same clock, and programmed to collect depth and velocity data at five (5) minute intervals.

Upon installation and activation of each flow meter, the Contractor took manual depth and velocity readings using an independent instrumentation to confirm that the in-situ monitor yielded data representative of actual field conditions. The field crews were required to take manual velocity readings of the cross-section (velocity profile) of the flow in order to determine the pipe hydraulic profile

2.4 Rainfall Measurement

The Contractor was required to measure the contribution from rainfall to all sewersheds within the City's jurisdictional boundary using a network of rain gauge stations with a minimum coverage of one (1) rain gauge station per ten (10) square miles, as well as data compiled by Doppler radar utilizing a minimum

resolution of one (1) pixel per four (4) square kilometers. To measure the contribution from rainfall occurring in portions of the Collection System outside Baltimore City limits, the Contractor installed additional rain gauges outside the City limits.

2.4.1 Equipment Description

The equipment consisted of a data logger able to accept data from an industry standard rain tipping bucket. The equipment was able to measure 0.1 inches (1mm) per tip of bucket. The tipping bucket consisted of a corrosion resistant funnel collector with tipping bucket assembly.

2.4.2 Installation

Most rain gauges were installed on the roof of public schools in the City and the County, and facilities owned by the City's Department of Public Works (such as pump stations and treatment plants).

2.4.3 Radar Rainfall

In accordance with the requirements of the Consent Decree, the City performed Doppler Radar Rainfall Analysis in conjunction with rain gauges at a resolution of 1 gauge for every 10 square miles. The Contractor utilized the CALAMAR software platform to process each recorded rainfall event with an average total depth of greater than 0.5 inches of rain. CALAMAR is a tool used to study the hydrologic impacts of precipitation through a combination of radar images and a network of rain gauges installed over a geographic area. CALAMAR uses three databases: a radar image database, a rain gauge database and a geographical database. After collecting the rain gauge network data and the radar images, CALAMAR produces a model that provides geographically accurate, integrated rainfall intensity data for any pre-defined area. The Baltimore City geographical area was divided into 1 square kilometer pixels, and for every significant rain event Doppler Radar rainfall images were generated for every pixel within the Back River and Patapsco WWTP service areas. There were a total of 29 storms were during the primary flow monitoring period. The dates of those storm events are listed in Table 5.

2.5 Ground Water Measurement

The Contractor installed groundwater gauges at 33 flow monitoring sites designated by the City. Each groundwater gauge consisted of a conduit (preferably a clear flexible tube) of sufficient diameter to accommodate a pressure sensor. The pressure sensor was calibrated prior to installation.

2.5.1 Equipment and Installation

The groundwater gauge connected through the manhole wall to the ground around the manhole near the bench of the manhole. The conduit was secured to the manhole wall or steps and extended vertically to a point 6 inches below the manhole lid. The connection through the manhole consisted of a drilled hole no larger than 1.25 inches in diameter, through which a PVC or metal pipe extended to approximately 6.0 inches outside the manhole and into the ground. At the end of this PVC or metal pipe a fine mesh was installed to let groundwater through but keep dirt and debris from clogging the pipe. The space between the manhole wall and the PVC or metal pipe was water-tight sealed with silicon caulking or similar material. The conduit connected securely to the PVC or metal pipe with the proper fittings and hardware to provide a water-tight connection.

2.6 Data Collection and Processing

The Contractor was required to use a host software support application program for remote wireless data collection of all flow meters, rain gauges, and ground water gauges. The host software maintained clock synchronization with the host system's clock for all field RTUs, thus insuring time interval integrity for all collected data. The City required the Contractor to use a system employing client/server architecture, capable of storing all project deliverables including flow and rainfall data; equipment configurations; event logs; and site parameters into a SQL database. The software allowed any networked computer (with the appropriate access rights) access to the data stored in the SQL database using a common web browser (e.g. Microsoft Internet Explorer). The web module was read only in order to protect data integrity, and had the ability to present near-real time data. Field data measurements could be forwarded to the server immediately following collection by the field RTUs, and the server could immediately post the data to the web site for viewing by authorized parties.

The Contractor was required to employ trained data analysts experienced in processing and analyzing flow and rainfall data from sanitary sewer systems. Various analytical tools, such as hydrographs, scattergraphs, and flow balancing methods were used to verify the accuracy and precision of the flow data. Data collection was performed remotely at least twice a week and was scheduled in a manner to allow data review by a trained data analyst within 24-hours of the data collection. The analyst assessed any maintenance or monitor performance issues, and a crew was dispatched within 48 hours, and the issue resolved within 72 hours from the time the issue was identified. All measurements, adjustments, and efforts undertaken during site visits were logged in an installation/maintenance log specific to that installation.

2.7 Monitoring Period

The period of flow metering extended from May 9, 2006 to May 18, 2007. Some meters deemed long term meters have stayed in place. See Table 4 for a list of meters, their sub-basin, purpose, and installation history.

2.8 Equipment Operation, Maintenance, and Uptime

The Contractor's qualified field crews visited each monitor installation as appropriate to perform any necessary maintenance to the equipment. As stated above, field crews were dispatched within 48 hours and any O&M issue was resolved within 72 hours from the time the issue was identified. The Contractor was required to collect useable flow data a minimum of 90% of the time throughout the monitoring period, and to submit to the City an "Uptime" table each month demonstrating compliance with the uptime requirement.

The uptime requirement would be generally satisfied with actual measured data. However, in instances where a velocity measurement was not available, inferred velocity from a reliable depth measurement would not be considered downtime if the Contractor demonstrated that accurate data could be obtained without the velocity measurement, and that the loss of velocity data was not caused by maintenance neglect. In any case, however, no velocity could be inferred for any measurement interval where (1) a corresponding depth measurement has not been obtained for that measurement interval or (2) independent calibration measurements have not been acquired for the site. The Contractor was required to identify all inferred velocity data or other data derived from inferred data in all reports and deliverables.

3.0 I&I Evaluation

3.1 Sliicer.com Wet Weather Analysis Tool

Sliicer is a tool developed by ADS Environmental Services, Inc. to find the locations of the worst inflow/infiltration problems in a sanitary sewer collection system using rainfall and flow data. By itself in its raw form, flow data can be difficult to interpret. The purpose of Sliicer is to make interpreting flow data easier, so that conclusions about what to do to enhance the performance of the collection system can be developed. Sliicer also allows the user to integrate flow data with physical inspection data to find the best approach to fixing the collection system. Finally, Sliicer generates the flow components necessary to calibrate the hydraulic model.

3.2 Global Settings

Global Settings are Sliicer parameters established by the City to be used by all Sewershed Consultants. These parameters should not be changed and will provide a necessary degree of standardization. Global settings include:

- The average dry day flow normalized by the linear feet contained in each sub-basin.
- The time step averaging will be 30 minutes.
- Criteria for defining dry days and which days should be excluded.
- Two seasons will be considered: Eastern Daylight Time and Eastern Standard Time.
- The threshold for a rain event to be considered in the analysis is 0.5 inches in 24 hours.
- The default method for computing wastewater production will be the Stevens-Schutzbach Method.
- The rolling method will be used for rainfall peaks.
- The units used are million gallons per day for flow rates, million gallons for volume, feet per second for velocity, and inches for flow depth.

3.3 Dry Weather Analysis

3.3.1 Dry Day Selection

Following the criteria established within the BaSES Manual, dry days were defined according to the following table:

TABLE 3 CRITERIA FOR DRY DAYS	
Number of Prior Days	Cumulative Antecedent Rain (Inches)
1	0.1
3	0.4
5	1.0

In addition, dry days with total flows that are 15 percent higher or lower than the average volume of all dry day were excluded from the analysis. Next the dry day traces for each meter were edited to remove any outliers that may have passed through the filtering requirements. Finally, Slicer calculated the Average Dry Flow (ADF) from all the traces.

3.3.2 Dry Day Groups

The dry-day groups used were weekdays and weekends. The weekdays include Mondays through Thursdays. Fridays were not included in either day group due to the flows patterns that occur within the Western Run sub-sewershed which are considerably different than the flow patterns that occur during the other days of the week. The weekends include Saturdays and Sundays.

3.3.3 Season Groups

The seasons used for the study were Eastern Daylight Saving Time (DST) and Eastern Standard Time (EST)

3.3.4 Waste Water Production and Base Infiltration Components

The wastewater production (WWP) was calculated by subtracting the base infiltration (BI) from the average dry flow (ADF). As required, the Stevens-Schutzbach Method was used to determine the base infiltration. The Stevens-Schutzbach Method is as follows:

$$BaseInfiltration = \frac{0.4 \times MDF}{\left(1 - \left(0.6 \times \left(MDF / ADF\right)^{MDF^{0.7}}\right)\right)}$$

Where: MDF = minimum dry flow

The gross infiltration rate was used for basins that exhibited negative net infiltration. Table 5 presents the results of the dry-weather analysis.

3.3.5 Base Infiltration Normalization by IDM

Normalizing BI is important when comparing basin with severe infiltration problems. Simply looking at infiltration rates does not always lead to the right conclusion about the location of the worst problems in the collection system. For this project, BI was normalized based on inch-diameter-miles (IDM). The IDM normalization was selected for BI because it takes into account not only the length, but also the diameter of the pipes in the basin. Regardless of the length, the larger the pipe diameter the more pipe surface is exposed to groundwater. Sliicer provides this type of BI normalization for each basin.

3.4 Wet Weather Analysis

3.4.1 Global Storms

A total of 29 storms during the metering period met the criteria for a storm event as defined by the global setting. The dates of these storms are listed in Table 6. Each storm was analyzed for each flow meter using the Sliicer.com software.

3.4.2 Pre-Composition Period

For each storm, a pre-composition period (typically 24 hours prior to the storm event) was established to adjust the dry day hydrograph to match the actual hydrograph immediately prior to the start of the storm. This either raises or lowers the dry day hydrograph so that the calculated rainfall-dependent infiltration and inflow (RDII) is a result of the storm event only.

3.4.3 Storm Measurement Periods

Sliicer.com calculates I&I for three periods following the start of the storm. They are called Storm, Recovery 1 and Recovery 2. Each period by default is 24 hours long which is set by the global settings. For this project, however, the storm periods were set by the City, are specific for each storm, and are long enough to capture all the RDII. The recovery periods 1 and 2 were set to 60 minutes, but are not used in any calculations.

3.4.4 RDII Calculations

In order to estimate the RDII, Slicer over-imposes the typical dry-day hydrograph on the storm hydrograph. The difference between the two hydrographs represents the RDII.

3.4.5 RDII Normalization

3.4.5.1 By Linear Footage

Normalizing the RDII is extremely important when comparing results to find the worst basins. Simply looking for the most raw wet weather flow does not always lead to the right conclusion about the location of the worst I&I problems in the collection system. Although raw I&I information is part of the picture, it needs to be correlated with basin size and rainfall information before it becomes useful. For this project, RDII was normalized based on linear footage (mg/l.f./in-of-rain). Slicer provides this type of normalization for each meter for each storm. The average of all storms was calculated.

3.4.5.2 By Area (Capture Coefficient)

A graphical technique for evaluating and comparing the performance of sewershed basins under widely varying rain events is the Q vs. I diagram. “Q” is the calculated I&I for a storm and “I” is the corresponding rainfall. The slope (S) of the regression line on the Q vs. I plot was used in the following equation to obtain the capture coefficient (R).

$$R = (36.83_{\text{(acres-in/mg)}} * S_{\text{(mg/in)}}) / \text{Area}_{\text{(acres)}}$$

The capture coefficient represents the percentage of the volume of rain water that fell on the basin that found its way into the collection system. Capture coefficients have been determined for both winter storms and for all storms, which are listed in Table 7. Plots of the Q vs. I diagrams for each flow meter are provided in the CD attached to this report.

4.0 Evaluation Results

4.1 Dry Day Results

The dry day results are shown on Table 5. As shown on this table, the base infiltration has been normalized by inch-diameter-miles (IDM). The basins with the highest base infiltrations rates are scattered throughout the Jones Falls Sewershed. The basin with the highest infiltration rate normalized by IDM is JF10, which is located within the Barclay Street sub-sewershed. Among the ten basins with the highest base infiltrations rates, two are located within the Western Run sub-sewershed, two are within the Upper Jones Falls sub-sewershed, two are in the Stony Run sub-sewershed, and one each are in the Barclay Street, Hampton Avenue, Maryland Avenue and Greenmount Avenue sub-sewersheds.

Figure 3 depicts the severity of the base infiltration, normalized by IDM. The infiltration rates were divided into five different ranges, as depicted on this figure.

From a sub-sewershed basis, the Maryland Avenue sub-sewershed has the highest base infiltration rate of approximately 7,400 gpd per IDM. The Barclay Avenue has a rate 95 percent of that of Maryland Avenue. The sub-sewershed with the lowest infiltration rate is Greenmount Avenue with a rate of approximately 2,795 gpd per IDM. The Western Run sub-sewershed is also low, less than one percent higher than the rate for the Greenmount Avenue sub-sewershed.

The base infiltration rate coming from Baltimore County is estimated from Meter TSJF01 located along the trunk sewer just south of the City/County line. Although there are a total of six boundary meters measuring flow from the County, Meter TSJF01 accounts for approximately 91 percent of the total. Approximately 31 percent of the average daily flow for this meter site is base infiltration based on the metering data. This value is lower than the average rate within the City. The base infiltration for this meter normalized by IDM is approximately 1,261 gpd per IDM.

4.2 Wet Weather Results

The RDII has been normalized by linear feet of pipe and inches of rainfall. These results are shown on Table 7. The RDII severity is also depicted on Figure 4. The basin with the greatest RDII severity is JF07 which is located within the Maryland Avenue, which has a value of approximately 37 MG per linear foot per inch of rainfall. There are a total of 17 basins which have a normalized RDII value greater than 10 MG per linear foot per inch of rainfall. Of these 17 basins, seven are located within the Western Run sub-sewershed, three each are in the Stony Run and Greenmount Avenue sub-sewersheds, two are in the Upper Jones

Falls sub-sewershed, and one each are in the Maryland Avenue and Barclay Street sub-sewersheds.

On a sub-sewershed basis, the Maryland Avenue sub-sewershed has the worst severity of RDII. Weighted by length of pipe, the overall RDII for the Maryland Avenue sub-sewershed is over 25 MG per linear foot per inch of rainfall. Other sub-sewersheds with relatively high rates of RDII are Western Run, Stony Run and Greenmount Avenue, all with weighted rates between 9 and 10 MG per linear foot per inch of rainfall. The sub-sewershed with the lowest rate of RDII is the Upper Jones Falls with a rate of approximately 6.1 MG per linear foot per inch of rainfall. The Bolton Hill and Hampton Avenue sub-sewersheds also have relatively low rates of RDII, close to that of the Upper Jones Falls.

There are six meters in the Jones Falls Sewershed that measures flow coming from Baltimore County. These meters are JF03_20S, JFWR15, JFWR31, TSJF01, BJF2 and BJF3. Flow coming to Meter TSJF01 represents a large portion of the total flow from the County. The total footprint for this meter is approximately 90 percent of the total footprint from the County. The flow basin with the highest RDII from the County is JF03_20S with a normalized value of approximately 11.9 MG per linear foot per inch of rainfall. Meter TSJF01, which accounts for the large majority of flow from the County, has a RDII value of approximately 2.4 MG per linear foot pre inch of rainfall. The other four flow basins have values that range from 3.5 to 7.2 MG per linear foot per inch of rainfall.

A review of the scattergraph plots included in the attached CD, shows evidence of possible sanitary sewer overflows (SSOs). The scattergraph for Meter JF04, in the Greenmont sub-sewershed, indicates evidence of a possible upstream overflow. The scattergraph for Meter JF10, in the Barclay Street sub-sewershed, indicates evidence of a possible SSO downstream of this site. A possible upstream SSO is suggested by the scattergraph for Meter JF40, in the Upper Jones Falls sub-sewershed. Scattergraphs that indicate possible bottlenecks include JF07 in the Maryland Avenue sub-sewershed, JF09 in the Barclay Street sub-sewershed, JF22 and JF23 in the Stony Run sub-sewershed, JF41 and JF47 in the Upper Jones Falls sub-sewershed, and JFWR18 and JFWRR01 in the Western Run sub-sewershed.

The scattergraphs were also reviewed to assess the hydraulic performance of the collection system. Within the Greenmount Avenue sub-sewershed, three of the six meters show no surcharging occurred during the metering period. The most frequent surcharging occurs at JF01, which is likely influenced by the sedimentation in the Jones Falls trunk sewer. At Meter JF02, surcharging was infrequent but reached a maximum depth of greater than 18 feet. Meter JF04 also surcharged and reached a maximum depth of less than seven feet. For the Maryland Avenue sub-sewershed, one of two meters did not surcharge during the

metering period. Meter JF07, however, did experience numerous cases of surcharging. This is due to sedimentation in the trunk sewer and the siphon located just downstream of this meter. In the Barclay Street sub-sewershed, which contains two metering basins, the downstream meter, JF09, experienced some surcharging to a maximum depth of approximately four feet. This may be influenced by the sedimentation in the trunk sewer. The scattergraph for the upstream meter, JF10, does not indicate any surcharging. The five meters within the Bolton Hill sub-sewershed indicate infrequent or no surcharging. The maximum depth, measured at Meter JF12, was approximately 5.5 feet. At the other meters, the maximum depth was less than 2.5 feet. For the Hampton Avenue sub-sewershed, four of the five meters indicate some, but infrequent, surcharging. The maximum depth recorded is less than three feet. In the Stony Run sub-sewershed, while the upper portions of this sub-sewershed show little or no surcharging, the lower portion indicates some significant surcharging. At Meter JF26, the highest degree of surcharging was recorded with a maximum depth of almost ten feet. Meters 21, 22, 25, 27 and 28 also show maximum depths of approximately 5.5 to 8 feet. In the Upper Jones Falls sub-sewershed, nine of the sixteen meters either show no surcharging or surcharged depths of 3.5 feet or less. At the other meters, there are some frequent and significant surcharge depths. The depths at these meters range from 6.7 feet to 12.9 feet with one instance of a depth greater than 25 feet at Meter 32. In the Western Run sub-sewershed, there are a total of 18 meters. Nine of these meters recorded no instances of surcharging, four had a maximum surcharged depth of two feet or less, and one had a maximum depth of less than four feet. The four remaining meters have maximum depths of 9.3 to 13.3 feet. Two of these meters, JFWR01 and JFWR01, are located along the main Western Run Interceptor near the Jones Falls trunk sewer. The other two meters with high surcharging are JFWR18 and JFWR19.

TABLE 4 LIST OF FLOW METERS, PURPOSE AND INSTALLATION HISTORY				
FLOW METER	SUB-BASIN	INSTALLATION PURPOSE	INSTALL DATE	REMOVAL DATE
JF01	Greenmount	I/I	5/9/2006	5/18/2007
JF02	Greenmount	I/I	5/9/2006	Long Term Meter
JF03	Greenmount	I/I	5/9/2006	Long Term Meter
JF04	Greenmount	I/I	5/9/2006	5/18/2007
JF05	Greenmount	I/I	5/9/2006	Long Term Meter
JF06	Greenmount	I/I	5/9/2006	5/18/2007
JF07	Maryland	I/I	5/9/2006	Long Term Meter
JF08	Maryland	I/I	5/9/2006	5/18/2007
JF09	Barclay	I/I	5/9/2006	Long Term Meter
JF10	Barclay	I/I	5/9/2006	5/18/2007
JF11	Bolton Hill	I/I	5/9/2006	Long Term Meter
JF12	Bolton Hill	I/I	5/9/2006	5/18/2007
JF13	Bolton Hill	I/I	5/9/2006	5/18/2007
JF14	Bolton Hill	I/I	5/9/2006	5/18/2007
JF15	Bolton Hill	I/I	5/9/2006	5/18/2007
JF16	Hampton	I/I	5/9/2006	5/18/2007
JF17	Hampton	I/I	5/9/2006	Long Term Meter
JF18	Hampton	I/I	5/9/2006	5/18/2007
JF19	Hampton	I/I	5/9/2006	5/18/2007
JF20	Hampton	I/I	5/9/2006	5/18/2007
JF21	Stony Run	I/I	5/9/2006	5/18/2007
JF22	Stony Run	I/I	5/9/2006	5/18/2007
JF23	Stony Run	I/I	5/9/2006	5/18/2007
JF24	Stony Run	I/I	5/9/2006	5/18/2007
JF25	Stony Run	I/I	5/9/2006	Long Term Meter
JF26	Stony Run	I/I	5/9/2006	5/18/2007
JF27	Stony Run	I/I	5/9/2006	Long Term Meter
JF28	Stony Run	I/I	5/9/2006	5/18/2007
JF29	Stony Run	I/I	5/9/2006	Long Term Meter
JF30	Stony Run	I/I	5/9/2006	Long Term Meter
JF31	Stony Run	I/I	5/9/2006	5/18/2007
BJF2	Stony Run	Calibration	5/9/2006	5/18/2007
BJF3	Stony Run	Calibration	5/9/2006	5/18/2007
JF32	Lower Jones Falls	I/I	5/9/2006	5/18/2007

TABLE 4 LIST OF FLOW METERS, PURPOSE AND INSTALLATION HISTORY				
FLOW METER	SUB-BASIN	INSTALLATION PURPOSE	INSTALL DATE	REMOVAL DATE
JF33	Lower Jones Falls	I/I	5/9/2006	5/18/2007
JF34	Lower Jones Falls	I/I	5/9/2006	5/18/2007
JFOUT	Lower Jones Falls	Calibration	5/9/2006	5/18/2007
JFS5	Lower Jones Falls	Calibration	5/9/2006	Long Term Meter
TSJF02A	Lower Jones Falls	Calibration	5/9/2006	Long Term Meter
TJSF02B	Lower Jones Falls	Calibration	5/9/2006	5/18/2007
JFZOO	Lower Jones Falls	I/I	5/9/2006	5/18/2007
JF35	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF36	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF37	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF38	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF39	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF40	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF41	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF42	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF43	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF44	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF45	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF46	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JF47	Upper Jones Falls	I/I	5/9/2006	5/18/2007
JFL	Upper Jones Falls	Calibration	5/9/2006	Long Term Meter
JFOF	Upper Jones Falls	Calibration	5/9/2006	Long Term Meter
JFPS	Upper Jones Falls	Calibration	5/9/2006	Long Term Meter
JFINL	Upper Jones Falls	Calibration	5/9/2006	Long Term Meter
TSJF01	Upper Jones Falls	Calibration	5/9/2006	Long Term Meter
JFWR01	Western Run	Calibration	5/9/2006	Long Term Meter
JFWRR01	Western Run	Calibration	5/9/2006	Long Term Meter
JFWR07	Western Run	I/I	5/9/2006	5/18/2007
JFWR09	Western Run	I/I	5/9/2006	5/18/2007
JFWR11	Western Run	I/I	5/9/2006	5/18/2007
JFWR12	Western Run	I/I	5/9/2006	5/18/2007
JFWR14	Western Run	I/I	5/9/2006	5/18/2007
JFWR15	Western Run	Calibration	5/9/2006	Long Term Meter
JFWR17	Western Run	I/I	5/9/2006	5/18/2007

TABLE 4 LIST OF FLOW METERS, PURPOSE AND INSTALLATION HISTORY				
FLOW METER	SUB-BASIN	INSTALLATION PURPOSE	INSTALL DATE	REMOVAL DATE
JFWR18	Western Run	I/I	5/9/2006	5/18/2007
JFWR19	Western Run	I/I	5/9/2006	5/18/2007
JFWR22	Western Run	I/I	5/9/2006	5/18/2007
JFWR24	Western Run	I/I	5/9/2006	5/18/2007
JFWR29	Western Run	I/I	5/9/2006	5/18/2007
JFWR31	Western Run	Calibration	5/9/2006	Long Term Meter
JFWR33	Western Run	I/I	5/9/2006	5/18/2007
JFWR34	Western Run	I/I	5/9/2006	5/18/2007
JFWR35	Western Run	I/I	5/9/2006	5/18/2007
JF03_20S	Western Run	Calibration	5/9/2006	5/18/2007

TABLE 5
DRY WEATHER ANALYSIS
DST - SUMMER 2006 - WEEKDAYS ONLY

Basin	A_{gross} (acres)	A_{net} (acres)	A_{net}/A_{gross} (%)	IDM (in-dia- mile)	ADF_{gross} (MGD)	ADF (MGD)	Q_{net}/Q_{gross} (%)	WWP (MGD)	BI_{net} (MGD)	BI Severity (gpd/idm)	BI Rate (%)	WWP Rate (gln/l.f.)
JF01	858.4	106.9	12.5%	26.69	1.888	0.115	6.1%	0.053	0.062	2323	53.9%	4.462
JF02	751.4	115.4	15.4%	53.96	1.807	0.054	3.0%	0.036	0.018	334	33.3%	1.198
JF03	636.1	155.6	24.5%	61.11	1.775	0.598	33.7%	0.516	0.082	1342	13.7%	17.638
JF0320S	77.1	77.1	100.0%	16.44	0.086	0.086	100.0%	0.044	0.042	2555	48.8%	4.053
JF04	165.1	165.1	100.0%	59.00	0.478	0.478	100.0%	0.258	0.220	3729	46.0%	7.241
JF05	315.3	219.8	69.7%	55.43	0.698	0.537	76.9%	0.156	0.382	6892	71.1%	5.152
JF06	95.5	95.5	100.0%	29.74	0.161	0.161	100.0%	0.122	0.039	1311	24.2%	6.566
JF07	187.3	134.8	72.0%	55.21	0.881	0.759	86.2%	0.239	0.520	9419	68.5%	8.544
JF08	52.5	52.5	100.0%	22.24	0.122	0.122	100.0%	0.070	0.052	2338	42.6%	5.041
JF09	294.2	146.6	49.8%	56.81	1.216	0.384	31.6%	0.143	0.241	4242	62.8%	4.397
JF10	147.7	147.7	100.0%	51.90	0.831	0.831	100.0%	0.310	0.522	10058	62.8%	9.730
JF11	602.1	183.4	30.5%	55.21	1.740	0.325	18.7%	0.015	0.309	5597	95.1%	0.450
JF12	418.8	135.2	32.3%	44.09	1.416	0.376	26.6%	0.319	0.057	1293	15.2%	12.842
JF13	283.6	112.2	39.6%	39.98	1.040	0.110	10.6%	0.055	0.055	1376	50.0%	2.352
JF14	171.4	78.4	45.8%	37.27	0.930	0.287	30.9%	0.160	0.128	3434	44.6%	6.906
JF15	93.0	93.0	100.0%	45.05	0.643	0.643	100.0%	0.375	0.268	5949	41.7%	13.260
JF16	613.0	121.5	19.8%	49.78	1.772	0.491	27.7%	0.010	0.481	9663	98.0%	0.351
JF17	491.4	135.5	27.6%	50.94	1.281	0.328	25.6%	0.244	0.084	1649	25.6%	9.737
JF18	102.0	102.0	100.0%	41.36	0.282	0.282	100.0%	0.109	0.172	4159	61.0%	4.180
JF19	253.9	127.1	50.1%	38.77	0.678	0.411	60.6%	0.180	0.232	5984	56.4%	7.431
JF20	126.8	126.8	100.0%	37.68	0.266	0.266	100.0%	0.141	0.125	3317	47.0%	5.770
JF21	2,519.0	215.3	8.5%	52.68	2.850	0.139	4.9%	0.092	0.047	892	33.8%	3.552
JF22	2,303.7	170.5	7.4%	45.76	2.884	0.486	16.9%	0.063	0.423	9244	87.0%	2.355

TABLE 5
DRY WEATHER ANALYSIS
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Basin	A_{gross} (acres)	A_{net} (acres)	A_{net}/A_{gross} (%)	IDM (in-dia- mile)	ADF_{gross} (MGD)	ADF (MGD)	Q_{net}/Q_{gross} (%)	WWP (MGD)	BI_{net} (MGD)	BI Severity (gpd/idm)	BI Rate (%)	WWP Rate (gln/l.f.)
JF23	173.4	173.4	100.0%	38.29	0.259	0.259	100.0%	0.111	0.149	3891	57.5%	4.115
JF24	1,959.8	180.7	9.2%	56.06	2.398	0.393	16.4%	0.080	0.313	5583	79.6%	2.143
JF25	1,779.1	205.9	11.6%	54.18	1.746	0.649	37.2%	0.577	0.073	1347	11.2%	16.665
JF26	547.8	222.2	40.6%	39.92	1.087	0.565	52.0%	0.230	0.335	8392	59.3%	9.723
JF27	325.6	152.2	46.7%	44.29	0.522	0.217	41.6%	0.132	0.085	1919	39.2%	4.756
JF28	173.4	173.4	100.0%	38.42	0.306	0.306	100.0%	0.161	0.145	3774	47.4%	6.531
JF29	1,025.5	194.9	19.0%	42.79	0.715	0.140	19.6%	0.005	0.136	3178	97.1%	0.181
JF30	830.5	255.6	30.8%	44.07	0.574	0.175	30.5%	0.044	0.131	2973	74.9%	1.765
JF31	575.0	209.1	36.4%	43.04	0.399	0.276	69.2%	0.154	0.122	2835	44.2%	5.895
JF32	84.9	84.9	100.0%	32.42	0.222	0.222	100.0%	0.084	0.139	4287	62.6%	3.999
JF33	73.0	73.0	100.0%	21.30	0.225	0.225	100.0%	0.076	0.150	7042	66.7%	5.478
JF34	237.2	237.2	100.0%	69.49	0.398	0.398	100.0%	0.209	0.189	2720	47.5%	5.074
JF35	118.5	118.5	100.0%	33.39	0.251	0.251	100.0%	0.086	0.165	4942	65.7%	4.034
JF36	52.6	52.6	100.0%	11.82	0.102	0.102	100.0%	0.071	0.031	2623	30.4%	9.047
JF37	358.4	176.5	49.2%	40.14	0.787	0.481	61.1%	0.219	0.262	6527	54.5%	9.572
JF38	181.9	181.9	100.0%	44.89	0.306	0.306	100.0%	0.129	0.177	3943	57.8%	4.742
JF39	75.0	75.0	100.0%	11.60	0.085	0.085	100.0%	0.058	0.027	2328	31.8%	7.943
JF40	181.5	181.5	100.0%	35.89	0.354	0.354	100.0%	0.209	0.146	4068	41.2%	9.146
JF41	217.2	217.2	100.0%	32.52	0.182	0.182	100.0%	0.108	0.074	2276	40.7%	4.259
JF42	183.0	183.0	100.0%	29.22	0.199	0.199	100.0%	0.083	0.116	3970	58.3%	3.832
JF43	385.0	385.0	100.0%	44.34	0.458	0.458	100.0%	0.257	0.200	4511	43.7%	9.612
JF44	73.7	73.7	100.0%	14.16	0.043	0.043	100.0%	0.031	0.012	847	27.9%	3.180
JF45	39.1	39.1	100.0%	8.28	0.066	0.066	100.0%	0.016	0.050	6039	75.8%	3.052
JF46	82.0	82.0	100.0%	12.45	0.123	0.123	100.0%	0.058	0.065	5221	52.8%	7.101
JF47	331.6	331.6	100.0%	44.90	0.280	0.280	100.0%	0.056	0.224	4989	80.0%	2.058

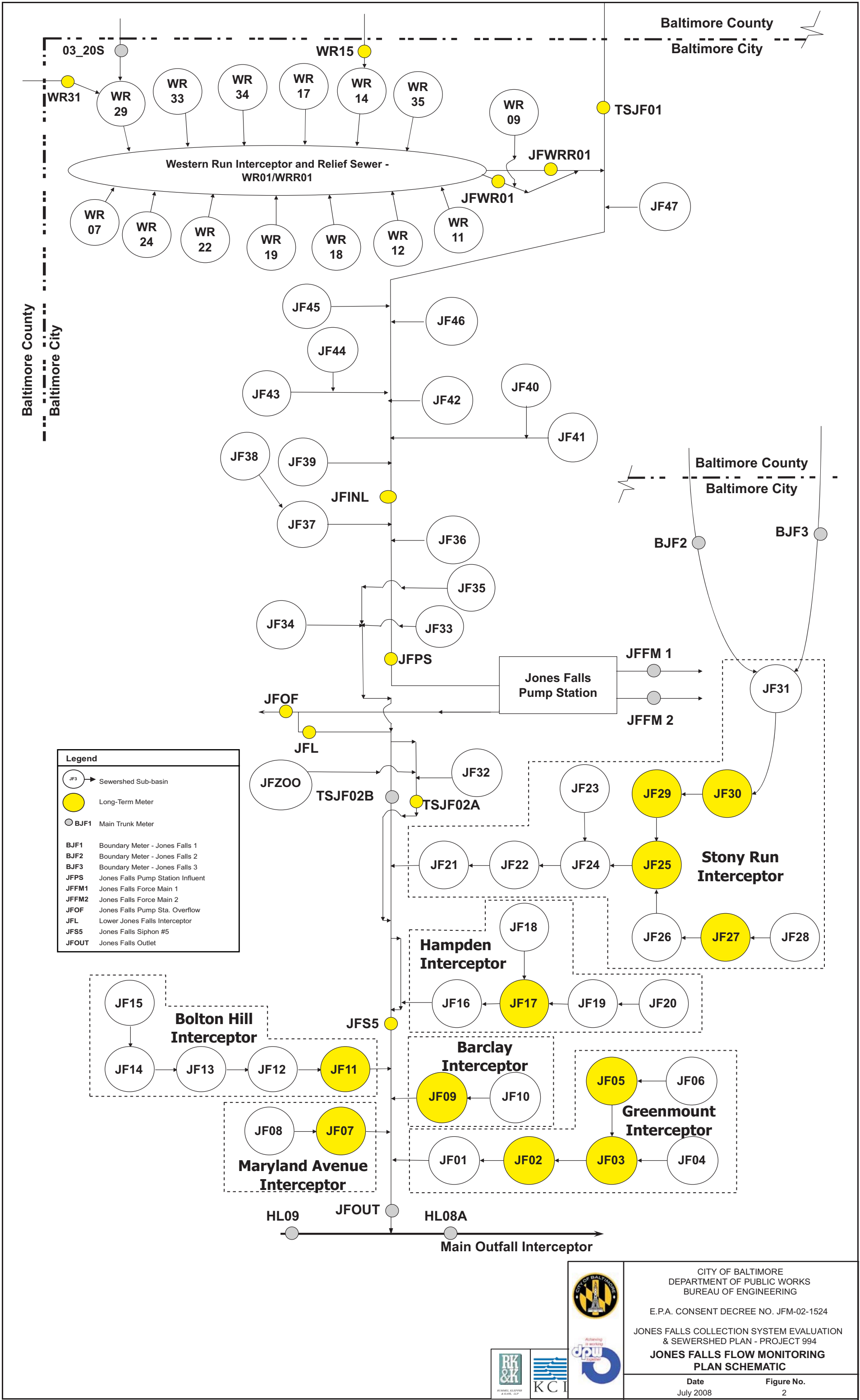
TABLE 5
DRY WEATHER ANALYSIS
DST - SUMMER 2006 - WEEKDAYS ONLY

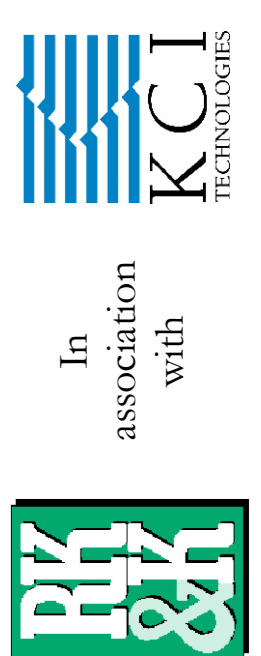
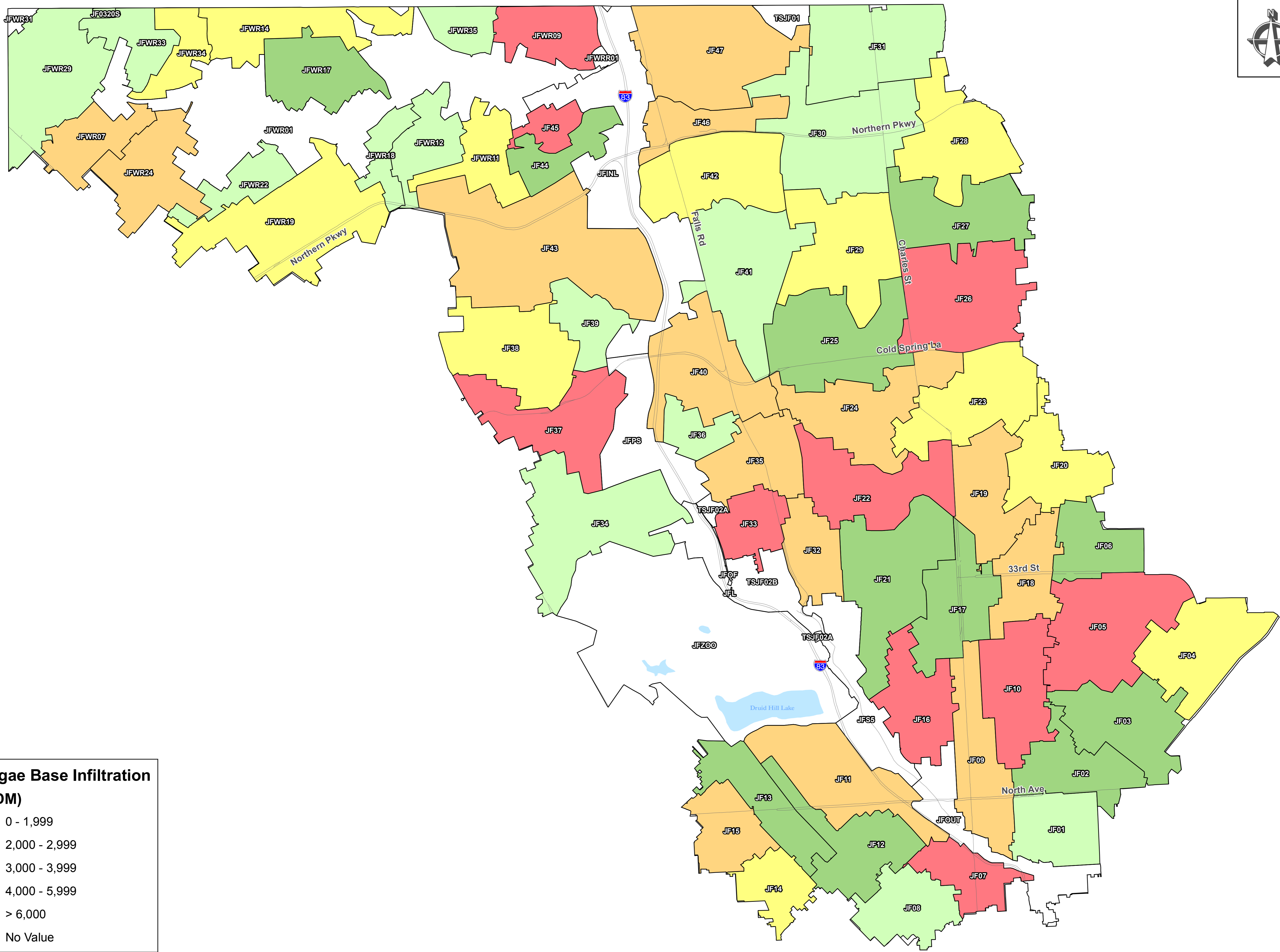
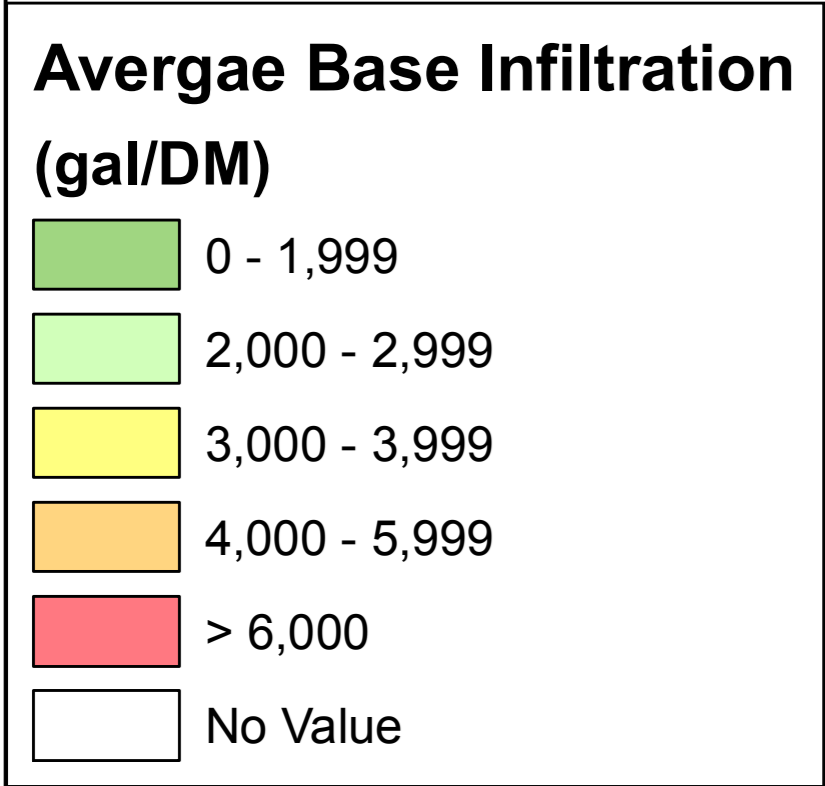
Basin	A_{gross} (acres)	A_{net} (acres)	A_{net}/A_{gross} (%)	IDM (in-dia- mile)	ADF_{gross} (MGD)	ADF (MGD)	Q_{net}/Q_{gross} (%)	WWP (MGD)	BI_{net} (MGD)	BI Severity (gpd/idm)	BI Rate (%)	WWP Rate (gln/l.f.)
JFWR07	88.9	88.9	100.0%	23.33	0.195	0.195	100.0%	0.089	0.107	4586	54.9%	6.307
JFWR09	143.3	143.3	100.0%	17.55	0.287	0.287	100.0%	0.146	0.141	8034	49.1%	12.632
JFWR11	90.8	90.8	100.0%	18.79	0.138	0.138	100.0%	0.075	0.064	3406	46.4%	5.897
JFWR12	84.4	84.4	100.0%	22.55	0.101	0.101	100.0%	0.039	0.063	2794	62.4%	2.613
JFWR14	500.8	261.6	52.2%	60.20	0.849	0.568	66.9%	0.357	0.211	3505	37.1%	10.095
JFWR15	239.2	239.2	100.0%	59.12	0.281	0.281	100.0%	0.207	0.074	1252	26.3%	5.411
JFWR17	122.1	122.1	100.0%	27.76	0.112	0.112	100.0%	0.073	0.039	1405	34.8%	4.030
JFWR18	49.2	49.2	100.0%	15.29	0.056	0.056	100.0%	0.024	0.031	2027	55.4%	2.408
JFWR19	257.1	257.1	100.0%	74.10	0.423	0.423	100.0%	0.168	0.255	3441	60.3%	3.607
JFWR22	65.5	65.5	100.0%	16.73	0.073	0.073	100.0%	0.029	0.044	2630	60.3%	2.597
JFWR24	133.5	133.5	100.0%	26.22	0.362	0.362	100.0%	0.232	0.130	4958	35.9%	14.147
JFWR29	1,506.7	268.4	17.8%	75.76	0.945	0.601	63.6%	0.413	0.188	2482	31.3%	9.718
JFWR31	1,161.2	1,161.2	100.0%	147.93	0.259	0.259	100.0%	0.076	0.183	1237	70.7%	0.863
JFWR33	107.3	107.3	100.0%	25.05	0.197	0.197	100.0%	0.129	0.068	2715	34.5%	8.539
JFWR34	65.1	65.1	100.0%	12.47	0.092	0.092	100.0%	0.052	0.040	3208	43.5%	6.261
JFWR35	102.7	102.7	100.0%	19.13	0.087	0.087	100.0%	0.049	0.039	2039	44.8%	3.922
JFZOO	604.7	604.7	100.0%	99.00	0.228	0.228	100.0%	0.077	0.151	1525	66.2%	774.438

TABLE 6 LIST OF GLOBAL STORMS		
Date	Depth (in)	Duration (hr)
May 11, 2006	1.678	8
May 14, 2006	0.79	16
June 2, 2006	0.179	2
June 19, 2006	0.554	5
June 24, 2006	0.85	4
June 25, 2006	5.238	39
July 5, 2006	2.311	12
July 22, 2006	1.276	9
September 1, 2006	1.935	26
September 5, 2006	1.629	8
September 14, 2006	1.638	38
September 28, 2006	1.015	7
October 5, 2006	1.728	44
October 17, 2006	1.136	9
October 19, 2006	0.56	12
October 27, 2006	1.634	30
November 7, 2006	1.472	15
November 16, 2006	2.244	9
November 22, 2006	0.551	11
December 22, 2006	0.938	15
December 25, 2006	0.57	42
December 31, 2007	0.843	12
January 7, 2007	0.833	17
March 1, 2007	0.922	15
March 15, 2007	1.996	26
March 23, 2007	0.53	15
April 4, 2007	0.302	5
April 11, 2007	0.622	17
April 14, 2007	2.664	31

TABLE 7 WET WEATHER ANALYSIS						
Basin	RDII (mg/l.f. - in)	Winter Capture Coefficient (R)		Basin	RDII Ranking (mg/l.f. - in)	Winter Capture Coefficient (R)
JF01	13.82	3.63%		JF07	1	1
JF02	8.22	29.30%		JF21	2	28
JF03	12.50	10.98%		JFWR24	3	2
JF04	8.84	12.94%		JF45	4	9
JF05	4.02	6.54%		JFWR33	5	6
JF06	10.23	14.65%		JFWR12	6	8
JF07	37.20	41.46%		JF01	7	53
JF08	5.41	8.56%		JF03	8	27
JF09	5.73	18.56%		JFWR11	9	16
JF10	10.54	11.31%		JFWR07	10	4
JF11	3.57	7.20%		JF24	11	12
JF12	5.13	3.74%		JF10	12	24
JF13	7.90	13.16%		JFWR18	13	5
JF14	8.23	13.38%		JF25	14	25
JF15	7.82	14.62%		JF37	15	31
JF16	3.21	4.48%		JF06	16	14
JF17	5.56	11.76%		JFWR22	17	10
JF18	9.65	15.23%		JFWR17	18	11
JF19	3.89	2.14%		JF18	19	13
JF20	9.36	12.26%		JF20	20	22
JF21	32.62	10.11%		JF22	21	55
JF22	9.08	2.73%		JF04	22	21
JF23	8.63	8.96%		JF23	23	30
JF24	11.10	15.27%		JF43	24	46
JF25	10.31	11.13%		JF14	25	19
JF26	4.73	1.75%		JF02	26	3
JF27	6.52	7.66%		JF32	27	18
JF28	7.69	6.27%		JFWR14	28	26
JF29	3.47	1.20%		JF13	29	20
JF30	3.46	0.91%		JF15	30	15
JF31	5.67	5.57%		JF28	31	44
JF32	8.14	13.72%		JFWR09	32	48
JF33	5.88	6.39%		JF38	33	38

TABLE 7 WET WEATHER ANALYSIS						
Basin	RDII (mg/l.f. - in)	Winter Capture Coefficient (R)		Basin	RDII Ranking (mg/l.f. - in)	Winter Capture Coefficient (R)
JF34	4.95	7.21%		JFWR19	34	17
JF35	4.47	8.20%		JF41	35	33
JF36	6.51	8.12%		JFWR34	36	37
JF37	10.26	8.80%		JF27	37	39
JF38	7.07	7.69%		JF36	38	35
JF39	3.53	2.59%		JFWR35	39	36
JF40	4.74	4.71%		JFWR29	40	29
JF41	6.60	8.23%		JF33	41	43
JF42	2.70	2.97%		JF09	42	7
JF43	8.54	5.25%		JF31	43	45
JF44	4.57	4.22%		JF17	44	23
JF45	17.69	17.88%		JF08	45	32
JF46	5.20	4.26%		JF46	46	50
JF47	3.33	2.58%		JF12	47	52
JFWR07	12.36	24.91%		JF34	48	40
JFWR09	7.08	4.61%		JF40	49	47
JFWR11	12.38	14.12%		JF26	50	59
JFWR12	13.99	17.96%		JF44	51	51
JFWR14	8.04	10.99%		JF35	52	34
JFWR17	9.68	17.18%		JF05	53	42
JFWR18	10.42	24.48%		JF19	54	58
JFWR19	6.73	14.05%		JF11	55	41
JFWR22	10.11	17.20%		JF39	56	56
JFWR24	23.71	30.84%		JF29	57	60
JFWR29	6.14	9.12%		JF30	58	61
JFWR33	15.80	22.81%		JF47	59	57
JFWR34	6.54	7.76%		JF16	60	49
JFWR35	6.40	7.94%		JF42	61	54





In association with
July 25, 2008
Scale: 1 inch = 0.25 miles

Average Base Infiltration

**Project 994 - Jones Falls
Collection System Evaluation
& Sewershed Plan**



FIGURE 3

